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COMPUTERIZED ADAPTIVE SCREENING TEST (CAST): DEVELOPMENT FOR USE IN MILITARY RECRUITING STATIONS

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The Computerized Adaptive Screening Test (CAST), which is capable of operating on a stand-alone microcomputer system in recruiting stations, was designed and developed to replace the Enlistment Screening Test (EST) currently in use. CAST correlates .87 with the Armed Forces Qualification Test (AFQT). It is being further refined. EST is used by all services; thus, as recruiting operations are automated, CAST has potential value to them all for reducing administrative and clerical burdens on the recruiter.

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FOREWORD

A joint-service coordinated effort is in progress to develop a computerized adaptive testing (CAT) system and to evaluate its potential for use in the military entrance processing stations as a replacement for the Armed Services Vocational Aptitude Battery (ASVAB) printed tests. The Department of the Navy (Headquarters, U.S. Marine Corps) has been designated as lead service for CAT system development; and the Navy Personnel Research and Development Center, as lead laboratory.

This report is the sixth in a series being issued under the CAT project. Previous reports described CAT system functional requirements and schedules, preliminary design considerations, the influence of fallible item parameters on adaptive testing, the relationship between corresponding ASVAB and CAT subtests, and a theoretical foundation for adaptive administration of aptitude tests (NPRDC Tech. Note 82-22 and Tech. Reps. 82-52, 83-15, 83-27, and 83-32).

This report describes the development of the Computerized Adaptive Screening Test (CAST), a screening test to be used at recruiting stations to predict ASVAB performance. CAST was developed in support of Advanced Computerized Adaptive Testing (Z1385-PN.01) and was described previously in NPRDC Spec. Rep. 83-36. Results are intended for use by the research community and, potentially, by all of the armed services.

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SUMMARY

Problem

Armed services recruiting faces serious challenges in the future, due to a shrinking pool of military eligibles. Added to vastly increased expenditures in recruiting caused by the move to an all-volunteer force (AVF) will be a fierce and costly competition for available personnel among colleges and the several armed forces, which will increase the difficulty of recruiting. The best available candidates for enlistment must be located, enlisted, and optimally assigned. Fiscal and personnel resources cannot be wasted; thus, recruiter tasks that detract from the primary mission of locating prospects and "selling the service" must be reduced.

Objective

The objective of the effort reported here was to design and develop the Computerized Adaptive Screening Test (CAST) that could: (1) operate on a stand-alone microcomputer system in recruiting stations, (2) reduce the recruiters' administrative burden, and (3) predict applicants' scores on the Armed Forces Qualification Test (AFQT) more efficiently than the Enlistment Screening Test (EST), a conventionally-administered, paper-and-pencil test used at present.

CAST Design and Development

1. Item banks were developed for the three CAST subtests (Word Knowledge, Arithmetic Reasoning, and Paragraph Comprehension). An ability estimation procedure for scoring and selecting test items was chosen, and a stopping rule for ending the test was determined.

2. The interactive dialogues were written for presentation on the video display terminal. Computer programs and software documentation were written for administering, scoring, and interpreting CAST on the microcomputer equipment at NAVPERSRANDCEN.

3. The CAST subtests were pilot-tested and statistical analyses were performed on the resulting data.

Results

In predicting AFQT scores, CAST was essentially as effective as the conventionally-administered, paper-and-pencil EST, while using fewer items.

Conclusions

CAST should prove superior to the EST in terms of administration and management and has been shown to be comparable in predictive power. It will relieve recruiters of clerical burdens associated with applicant screening, making additional time available for effective recruiting duties. Suitable for use with computer-naive personnel, CAST will improve test security, reduce compromise, and reduce one source of recruiter malpractice. It will enhance the image of military recruiting and place the implementing service in a forward position regarding addition of other screening instruments, test revision, and so on.

Recommendations

It is recommended that the recruiting command of the using armed service:

1. Administer CAST to service applicant populations. Analyses could be conducted on the data obtained to establish a cutting score for use in determining whether to send an applicant to a military entrance processing station or mobile examining test site for ASVAB testing.

2. Investigate the suitability of the CAST interactive dialogue, system-user interface, and its effect on recruiting operations.

3. Refine CAST, as appropriate, to achieve recruiter and applicant acceptance.

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Background and Problem

Armed services recruiting faces serious challenges in the future, due to a shrinking pool of military eligibles (Congressional Budget Office, 1980). The all-volunteer force (AVF) concept has led to vastly increased expenditures in recruiting (Office of Naval Research, 1979). The results will be a fierce and costly competition for available personnel among colleges and the several armed forces, which will increase the difficulty of recruiting (Joint Chiefs of Staff, 1982). The best available candidates for enlistment must be located, enlisted, and optimally assigned. Fiscal and personnel resources cannot be wasted; thus, recruiter tasks that detract from the primary mission of locating prospects and "selling the service" must be reduced.

The screening of applicants for enlistment, which takes place near the end of the recruiting process, includes, as a major element, the administration of the Armed Services Vocational Aptitude Battery (ASVAB), a 10-test battery given to all armed services applicants. To be eligible for enlistment, an applicant must achieve a minimum Armed Forces Qualification Test (AFQT) score, which is a linear composite of the scores obtained on four ASVAB tests. The ASVAB is given to a large number of high school students through the Department of Defense High School Testing Program and to service applicants (unless they have previously achieved a qualifying AFQT score) at a military entrance processing station (MEPS) or mobile examining test (MET) site.

Transportation from a recruiting station to a MEPS/MET site entails costs for the transportation and, in many cases, for meals and lodging. Costs are also incurred for personnel time at both the recruiting station and the test site. If applicants are sent to the MEPS/MET site and subsequently fail the ASVAB, there is a significant waste of money. Conversely, if applicants who would have passed are erroneously denied ASVAB testing, their talents are lost to the service, social costs accrue to the applicants, and (in a tight recruiting market) pressure on recruiters to obtain a replacement applicant is increased.

Aptitude screening to predict the AFQT score originated because of the need for expenditure control. However, since results are used early in the recruiting process to decide whether an applicant should be sent for ASVAB testing or rejected, the accuracy of those results have great impact on both the armed services and the applicant. Accordingly, aptitude testing assumes a critical importance (Maier & Fuchs, 1973).

Currently, all armed services use the Enlistment Screening Test (EST) at recruiting stations to predict applicant AFQT scores. EST is composed of 3 subtests totaling 48 items, with a total time limit of 45 minutes. It was developed by the Air Force Human Resources Laboratory in 1976 (Jensen & Valentine, 1976) and revised in 1981 (Mathews & Ree, 1982).

Pure measurement error does not seem to be a problem with the EST; it appears that the newer test forms (81a and 81b) provide adequate measures throughout the score range where most selection and classification decisions are made and it correlates .83 with the AFQT (Mathews & Ree, 1982). However, EST does share in the problems of adverse psychological effects. It is a conventionally-administered, paper-and-pencil type of test, which has been shown to be associated with high levels of guessing, frustration, and boredom in subjects (Vale & Weiss, 1975; Weiss, 1974). In their customary delivery mode,

conventional paper-and-pencil tests actually combine the worst features of individually-administered tests (i.e., they are heavily dependent upon variables associated with the examiner or the examiner-examinee relationship) and group tests (i.e., item arrangement, item set, answer sheet effects, and imprecision) (Weiss & Betz, 1973). EST is scored on a pass/fail basis. Since EST is also a timed test, it exerts differential pressure on the examinees (i.e., results are based partly upon individual reaction to time constraints (Weiss, 1974)).

Major concern focuses on administrative error and clerical burden. EST requires approximately 45 minutes to administer, plus the time required to score and interpret results and to manage the test supplies (by a recruiter already investing many hours in the potential enlistee). At present, besides storing, filing, retrieving, and ordering replacements, the recruiter is required to take frequent inventory, make numerous checks and corrections for unauthorized markings in the test booklets, and safeguard used answer sheets. EST is thus highly labor intensive, consuming the time of a senior noncommissioned officer in quasi-clerical tasks.

Since only two forms of EST are in use, the failing subject can hope to pass the test eventually by repeated testing and item memorization. If more contraindicators were needed, many are apparent: (1) the initial and replacement costs and short life of materials associated with paper-and-pencil tests, (2) the poor impression created by dilapidated materials, and (3) security, custody, and control difficulties. In short, to reduce the recruiter's task load, there is a critical need for a predictive instrument that is more effective and a screening method that is easier to administer.

Computerized adaptive testing (CAT) (McBride, 1979) combines recent developments in latent trait theory with the ever-increasing power and efficiency of computers. The result is employment of individualized testing without the loss of administration efficiencies gained through group testing, combining advances in computer technology with those in psychometrics, and using computers to administer tests that adapt themselves to individual differences in ability levels during their administration (Pine, Church, Gialluca, & Weiss, 1979). The difficulty level of an adaptive test is dynamically tailored to the ability of each subject. Also, because each subject receives a tailored subset of items, the chances of test compromise through copying, memorization, or pretest coaching are lessened.

With adaptive testing, shorter tests may be used without loss of reliability or validity (Betz & Weiss, 1975; Weiss, 1974). Adaptive tests are untimed, reducing pressure on the subject without hindrance to the proctor (Weiss, 1976). Adaptive testing reduces boredom and frustration (Weiss, 1974), guessing (Betz & Weiss, 1975), real or perceived proctor-subject bias (Gorman, 1977), and culturally-specific racial bias (Pine, 1977). Adaptive testing is more motivating than conventional testing, thereby eliciting "best results" from subjects (Betz & Weiss, 1976) and more accurately reflecting subject competence (Pine, 1977).

Computerized testing has its own merits. It may lessen test bias through item selection and increase test fairness by the nature of the test itself and the test's administration modality (Pine et al., 1979). The computer makes it possible to eliminate printed test materials and their associated logistical, security, and administrative problems, while facilitating item replacement, whole test construction, and the capturing of data for validation purposes.

After each CAT question, the computer can use the response information to update the ability estimate and then use the new estimate of ability to select the next item.

With each successive response, the ability estimate gains reliability. The process can continue until some stopping rule is satisfied (e.g., a fixed number of questions administered or a prespecified level of reliability). CAT can shorten testing time without a loss of test effectiveness, as well as eliminate scoring and recording errors due to clerical error (Gorman, 1977).

Objectives

The objectives of the effort reported here were to design and develop a Computerized Adaptive Screening Test (CAST) that could: (1) operate on a stand-alone microcomputer system in recruiting stations, (2) reduce the recruiters' administrative burden, and (3) predict applicants' scores on the AFQT at least as accurately as the paper-and-pencil EST used at present.

CAST DESIGN AND DEVELOPMENT

Designing and developing CAST required parallel work in psychometrics and computer programming.

Test Construction

CAST was envisioned as incorporating three subtests that would correspond to three of the four ASVAB tests used to calculate the AFQT composite score: Word Knowledge (WK), Arithmetic Reasoning (AR), and Paragraph Comprehension (PC) (Sands, 1981).[1] Item banks for the CAST subtests were assembled in conjunction with the University of Minnesota for use in CAT ASVAB research (Moreno, Wetzel, McBride, & Weiss, 1983) and were made available for the present research effort. These item banks included 78 WK items, 247 AR items, and 25 PC items, together with the estimates of three parameters (discrimination, difficulty, and guessing) for each item.[2] A Bayesian ability estimation procedure described by Jensema (1977) was chosen for scoring and determining the selection and presentation sequence of test items. The stopping rule selected was the administration of a fixed number of items.

Computer System Hardware and Software

Computer hardware used for development of CAST included:

1. Applied Computer Systems (ACS) microcomputer.
2. Perkin-Elmer Data Systems 1200 video display terminal (VDT).

CAST computer programs were written to provide interactive, user-friendly software that presumed no previous computer experience on the part of either recruiter or applicant. In addition, all VDT screen text displays were written, reviewed, and edited for readability (reading grade level) standards. Figures 1 and 2 illustrate a sample of an instructional display and a demonstration test item. To facilitate user acceptance, the time between item response and presentation of the next item generally should not exceed 3 seconds. This goal was accomplished.

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[1]The fourth test is Numerical Operations (NO); the AFQT formula is AR + WK + PC + .5NO.

[2]The AR test item bank was reduced to 225 items after removal of superfluous items. The WK and PC item banks remain at 78 and 25 items respectively.

You will now be given the Computerized Adaptive Screening Test (CAST). This is an aptitude test designed to predict how well you will do on the Armed Services Vocational Aptitude Battery (ASVAB).

In order to qualify for enlistment, you must get a passing score on the ASVAB. The test you will now take will give you an idea of how well you can expect to do on the ASVAB.

***Press GO to continue.

Figure 1. Sample of an instructional display.

The following item is for practice only and will not be counted in scoring your test.

Children enjoy ______ in the sandbox at the park.

1. Understanding.
2. Finding.
3. Working.
4. Playing.

Your answer is? ____

Figure 2. Sample of a demonstration test item.

Software documentation for presentation of CAST on the ACS microcomputer system was completed. Subsequently, the program was converted to operate on an Apple II-Plus microcomputer with two disk drives and a VDT.

Test Administration

In each CAST subtest, a provisional ability estimate is made, a test item appropriate to that ability level is presented, and the ability estimate is updated based on the response to the test item. The computer program for this iterative ability estimation process starts by associating each examinee with an ability level. Selection of a test item starts from the top (highest information value within a level) and searches for the first item not yet presented. The item that results from this search is then presented. Based on the prior ability estimate and the examinee's correct or incorrect response, the ability estimate is updated, and the next test item is selected for presentation from the new ability elvel. This process continues until the stopping rule is satisfied.

Test Validation

Moreno et al. (1983), in their research to assess the relationship between corresponding ASVAB and CAT subtests (WK, AR, and PC) provided a de facto pilot test of CAST. The three CAST subtests were administered during a 90-day period late in 1981 to 356 male recruits at the Marine Corps Recruit Depot, San Diego. Each recruit had

taken the ASVAB before enlistment and was retested on a parallel form of ASVAB during recruit processing. After eliminating subjects with missing scores on any test and those who had been administered forms of ASVAB that were no longer in use, the remaining sample was 270.

In the CAST pilot test, each subtest was administered with a fixed length: 15 items each for WK and AR, and 8 items for PC. All examinees began with the same item, which was of medium difficulty. The adaptive tests were conducted without time limit. A preliminary introduction to the testing situation was delivered orally by the proctor, while all other instructions, including use of the terminal and procedures for answer entry and changes, were presented on the terminal screen. Practice preceded each subtest and successful response to practice items was necessary prior to beginning the subtest. The test was administered, by computer, on four terminals in a specially designated testing room. The terminals were on-line with a Hewlett-Packard 21 MX computer at the University of Minnesota, through a data communications line.

There were several differences between CAST as it was designed to be given and the subtest administration during the pilot test described herein. A true backspace key was not available on the terminal, requiring the recruit subjects to use the "Rubout" key to make corrections. In the PC subtest, the stimulus paragraphs did not remain on the screen while the response alternatives were displayed. The pilot test was administered on terminals communicating with a host computer, while CAST is designed for use on a stand-alone microcomputer with attached disk drives. Finally, because of prior selection by the Marine Corps, the recruits tested were not representative of an unselected applicant population.

After test scores were collected, the relationships between CAST subtests (AR, WK, and PC) and their ASVAB counterparts were evaluated through correlational analysis. The ability of the CAST subtests to predict AFQT score was assessed using multiple regression analysis.

RESULTS

Each CAST subtest correlated as well with its ASVAB counterpart as did the parallel form ASVAB retest score (see Table 1). The multiple correlation of the CAST subtests with AFQT score was .866 (see Table 2).

Notwithstanding the differences between CAST administration as originally designed and as carried out in the Marine recruit testing, the results of the recruit testing are significant. It was clearly demonstrated that military recruits (and, by implication, military applicants) could be tested by computer terminal with minimal intervention by a proctor. The CAST subtests measured the same abilities as the corresponding ASVAB tests, using about half the number of qustions (Moreno et al., 1983).

Table 1

Intercorrelations Among CAST, Initial ASVAB, and Retest ASVAB Tests
of Word Knowledge (WK), Arithmetic Reasoning (AR),
and Paragraph Comprehension (PC) in a Sample
of 270 Marine Recruits

Test	1	2	3	4	5	6	7	8	9	10	Mean	Std. Dev.
1. Initial ASVAB: AR	1.000	0.481	0.457	0.767	0.417	0.491	0.800	0.530	0.429	0.836	21.77	5.41
2. Initial ASVAB: WK		1.000	0.573	0.495	0.771	0.516	0.501	0.806	0.486	0.785	28.17	4.89
3. Initial ASVAB: PC			1.000	0.496	0.523	0.464	0.508	0.554	0.507	0.687	11.78	2.20
4. Retest ASVAB: AR				1.000	0.483	0.548	0.800	0.564	0.495	0.764	21.43	5.71
5. Retest ASVAB: WK					1.000	0.581	0.490	0.799	0.533	0.657	28.06	4.86
6. Retest ASVAB: PC						1.000	0.496	0.598	0.505	0.618	11.48	2.50
7. CAST: AR							1.000	0.579	0.525	0.788	0.401	0.82
8. CAST: WK								1.000	0.560	0.748	0.588	0.79
9. CAST: PC									1.000	0.542	0.077	0.85
10. AFQT composite										1.000	82.03	11.81

Table 2

Correlations of CAST Subtests and Composites with AFQT
(N = 270)

Predictor Variables	Validity
CAST: Arithmetic Reasoning (AR)	r = .788
CAST: Word Knowledge (WK)	r = .748
CAST: Paragraph Comprehension (PC)	r = .542
Optimally Weighted Composite (AR, WK)	R = .865
Optimally Weighted Composite (AR, WK, PC)	R = .866

DISCUSSION

A microcomputer-based CAST demonstration system has been developed, with complete documentation for all software. User-friendly, interactive software provides full screen display, clearing the screen after each display. Response time is 3 seconds or less. An easily used backspace key and an error-trapping capability that ensures recruiter assistance after repeated procedural errors by the applicant have been added to the system. Figure 3 presents a flow diagram of the CAST process.

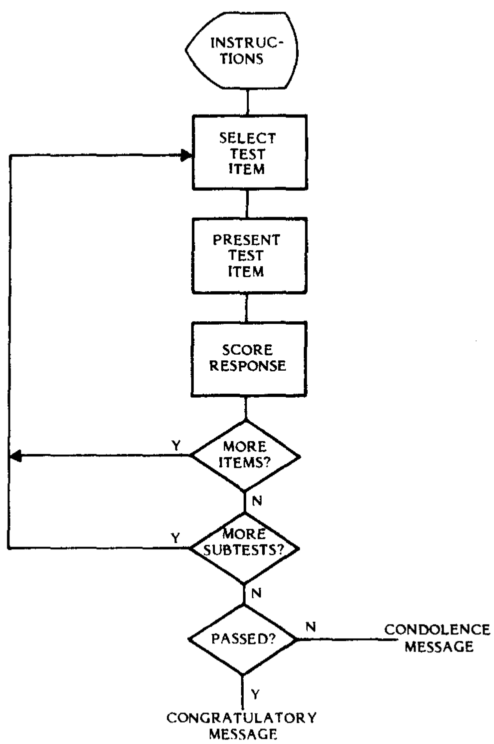

Figure 3. Flow chart of the CAST process.

Follow-on research and development with CAST will evaluate the interactive screen dialogues for readability and user friendliness with service applicants. Capitalizing on the results of the pilot testing of the subtests, it appears entirely feasible to eliminate the PC subtest from CAST without a significant decrement in the correlation between the CAST linear composite and AFQT (see Table 2) (Moreno et al., 1983). Examination of the data suggests that the length for the AR and WK subtests could be set at 7 and 15 items respectively, without appreciable loss in predictive validity. Were both procedures to be implemented, the correlation between AFQT and CAST would drop only to $R = .865$ (from .866), still comparing favorably to that of AFQT with the current EST ($r = .83$). The result would be a CAST comprised of only two subtests, requiring an average of 16 minutes for complete administration, scoring, and interpretation, as opposed to 45 minutes for the EST administration alone, a significant savings.[3]

CONCLUSIONS

The development of CAST represents the serendipitous merging of three elements: (1) research on a CAT instrument to replace the EST, (2) item banks developed under a separate research effort, and (3) the planned automation of recruiting operations that will presumably place microcomputers in recruiting stations.

CAST can be regarded as successfully developed, requiring only minor refinements. It should prove superior to the EST in terms of administration and management and has been shown to be about equal in predictive power. CAST eliminates the need for traditional test materials, thereby saving storage space, replacement costs, and recruiter time formerly used for administering the tests and controlling and maintaining test materials. With CAST, test loss and theft would be all but eliminated and compromise should be reduced. Security could be maintained by a built-in user password or identification. Rather than serving as a test proctor-scorer, the recruiter simply would manage a computer-subject dialogue, with a self-scoring test for which results are immediately available and may be automatically stored for later use.

Savings in money and time would result by eliminating traditional test materials and reducing recruiter time spent in testing. In short, CAST will decrease negative psychological effects, decrease administrative error, and increase test security.

CAST is important not only for its present economizing service but also for its enabling functions. Implementing CAST will allow the implementing service to be highly responsive to advances in psychometrics and managerial science, as well as enable it to implement further applications rapidly when they are needed. It is predicted that computerized ability testing systems will find their optimal use in organizations serving populations of wide-ranging ability (De Witt & Weiss, 1974). With CAST, the using service will be in the forefront of CAT implementation. When implemented, CAST will probably be the first large-scale operational use of computerized adaptive testing.

In today's recruiting climate, where increased screening capabilities assume ever greater importance, the using service will have the technological base upon which to mount other screening instruments for both selection and classification. These might include (1) predictors of tenure and effectiveness (Sands, 1976, 1977, 1978), (2) assessment of expectations, intentions, job perceptions, and attitudes (Horner, Mobley, & Meglino, 1979), and (3) screening for specific placement. Screening could be significantly

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[3]McBride, J. R. Personal communication, October 1982.

improved by expanding the array of measures to include special abilities and even biodata (Swanson & Rimland, 1970), since the administration and motivational problems associated with lengthy testing and examinee fatigue would be reduced by automation.

Tangentially, future test development costs and intrusion on operating systems will be reduced because experimental test items can be introduced within CAST in a manner that is transparent to the field user. This will facilitate the development and evaluation of new items. Test administration will be standardized, fairer to all applicants, and far more efficient in scoring and recording methods.

RECOMMENDATIONS

It is recommended that the recruiting command of the using armed service:

1. Administer CAST to service applicant populations. Analyses could be conducted on the data obtained to establish a cutting score for use in determining whether to send an applicant to a military entrance processing station or mobile examining test site for ASVAB testing.

2. Investigate the suitability of the CAST interactive dialogue, system-user interface, and its effect on recruiting operations.

3. Refine CAST, as appropriate, to achieve recruiter and applicant acceptance.

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